The Breeding of Fur Animals

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THE BREEDING OF FUR ANIMALS

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THE science of breeding can play an important part in conserving and developing the fur resources of the United States in two vital ways. (1) Research is needed to throw light on the breeding habits and gestation periods of wild fur animals so that an intelligent conservation program may be based on the biological needs of the animals concerned. (2) As in the case of domesticated livestock, breeding research is needed to give a more certain foundation for the production of fur animals in captivity—notably the silver fox and the mink. To state which of these two fields is the more important is difficult. Without a vigorous conservation program based on sound scientific knowledge there is great risk of completely wiping out one of the oldest of the valuable resources of the country. On the other hand, fur farming is rapidly becoming an important farm enterprise, and if it is to develop its full possibilities, further information is greatly needed at various points. The industry is all the more significant because it does not compete with any other kind of farming and it utilizes land that is of little or no value for any other crop.

A brief backward glance will show what has happened to the fur resources of the United States to make conservation in the wild so essential and propagation on fur farms a lucrative undertaking of such great promise. In almost every civilization furs have been among the most valued articles of commerce. This was true among the Chinese 3,500 years ago, and later among the Greeks and the Romans. In medieval Europe fur was a luxury much sought after—and incidentally, men made greater use of it for clothing than did women. It was not until after the discovery of North America, of course, that the world fur trade really got into its stride. That it early became an enormously profitable business on this continent is attested by the fact that an Indian trapper could often be induced to part with his winter's catch, worth hundreds of dollars, for a blanket or two and a bottle of rum—and perhaps not very good rum. Among the great fortunes amassed in this game the outstanding example is that of John Jacob Astor.

In these circumstances, with pelts readily obtained and profits large, no attention whatever was paid to the question of the possible exhaustion of this source of wealth that nature distributed with a prodigal hand. The more furs there were on the market, the more popular furs became. The luxury of the rich became the necessity of the moderately well to do. The trap lines were run not less but more intensively, to the profit of everyone—the professional trapper, the landowner, the farmer who could turn a few extra dollars without much trouble, and a large army of wholesalers, factory owners and workers, and retailers and their employees.

Naturally a depletion of fur resources resulted. This cannot be attributed, however, entirely to overeagerness in trapping. The disappearance of the wilderness, natural habitat of the fur-bearing animals, was a major factor. Nevertheless, even today the trappers and fur farmers of the United States receive $60,000,000 a year for the raw furs they bring to the market. The annual retail turn-over is several times that amount; in 1929, the peak year, it reached half a billion dollars. The United States is in fact the largest consuming market in the world.

PRODUCTION AND DEMAND FOR FURS

TODAY, instead of the United States being the world's chief source of fur supply, this country does not produce enough to meet more than a third of its own demand. Twice as many foreign as domestic furs are now being used in this country, and the demand is increasing rather than decreasing. To meet this demand, trappers still take fur animals from the wild with the same extravagant disregard of maintaining or increasing whatever supply is left. It is unquestionable that our natural fur resources will be completely exhausted, unless measures are taken to strike a proper balance between supply and demand.

In this connection there is much need for greater knowledge regarding production. At present no one knows what would constitute

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BEFORE *the development of fox farming there apparently occurred in the common red fox two distinctly different mutations to black (silver)—one among foxes in Canada, giving rise to what are now called standard silvers, and one among foxes in Alaska, giving rise to Alaskan silvers. Beginning in 1928 the Bureau of Biological Survey conducted research to determine the inheritance of the major color types, and B. L. Warwick and the late Karl B. Hanson worked out a hypothesis according to which two dominant genes, A and B, and their recessives, a and b, accounted for all the principal color variations. The results of experimental crosses and an analysis of a large number of litters from recorded matings made by fox farmers substantiated this hypothesis. By referring to a simple genetic chart, it is now possible to determine the expected results of any method of breeding the nine basic combinations of these two pairs of genes. This research indicates the possibilities in the study of the inheritance of fur color, which is of primary importance in fox farming.*

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a proper balance. We do not know, for example, whether we are producing 10,000,000 muskrats a year and trapping 13,000,000 or producing 5,000,000 and trapping 25,000,000. We can be pretty sure that we are trapping more than we are producing; but it is important to find out how many more. Almost every State has some fur resources that are a source of income for some of its citizens. The methods of handling these resources are almost entirely haphazard, and in fact few State game and conservation commissions have given sufficient serious thought to the matter. In most States there is no provision for keeping a record of the furs taken each year. In the case of some of the most valuable fur bearers—martens, fishers, wolverines, and otters—the situation has become so serious that the Bureau of Biological Survey has appealed to all State game and conservation commissions to protect them with a 5-year closed period, as the only way to forestall their extermination.

REPRODUCTIVE CYCLES

THE usefulness of breeding data in this situation may be illustrated by the case of the marten (fig. 1). At its experiment station near Saratoga Springs, N. Y., established in 1923, the Bureau has been studying the breeding and the gestation period of the marten. As a result it has found that a period of 9½ months elapses between the time of copulation and birth. With so long a period of gestation, many pregnant females are bound to be destroyed under the prevailing system of open and close seasons. It is obvious that unless the trapping season for a fur animal corresponds accurately with its gestation-free period, the close season will not accomplish what it is intended to: the prospective generation will be destroyed along with the one trapped. Even this precaution, however, would be ineffective in the case of the marten or the fisher, for their gestation periods are too long. A 5- or 10-year closed period is necessary to prevent local or even general extermination of these two fur animals.

The available information on the reproductive cycles of the wild fur-bearing animals is very meager. A review of the literature shows that very little research has been conducted to determine their actual breeding seasons, postnatal development, and gestation periods. Practically all that is now known has been learned by observing the living animals. Few investigators have studied actual embryological material. The one outstanding contribution to the embryological science of fur animals is that of Hartman,[1] of the Department of Embryology, Carnegie Institution of Washington, at Baltimore, Md. This paper presents a study of the physiology of growth and reproduction, the embryology, the rate of intra-uterine and postnatal growth, and the breeding season. More information of this kind is vitally important to any programs of conservation, restoration, restocking, or transplanting, as well as to the success of any effort to produce fur species in captivity. Conversely, it is also important in successful control of noxious animals, which should be most intensively hunted throughout the period preceding the arrival of the young. Similarly important is definite knowledge of the molting and

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[1] HARTMAN, C. G. THE BREEDING SEASON OF THE OPOSSUM (DIDELPHIS VIRGINIANA) AND THE RATE OF INTRA-UTERINE AND POSTNATAL DEVELOPMENT. Jour. Morph. and Physiol. 46: 143-215. 1928.

prime-fur cycles, for, with dependable data at hand, trapping may be confined to the time when a given fur has its maximum value. At present this is rather vaguely considered to be the period of cold weather.

This kind of knowledge is fragmentary in comparison with what has been developed in the case of the domestic animals, which have

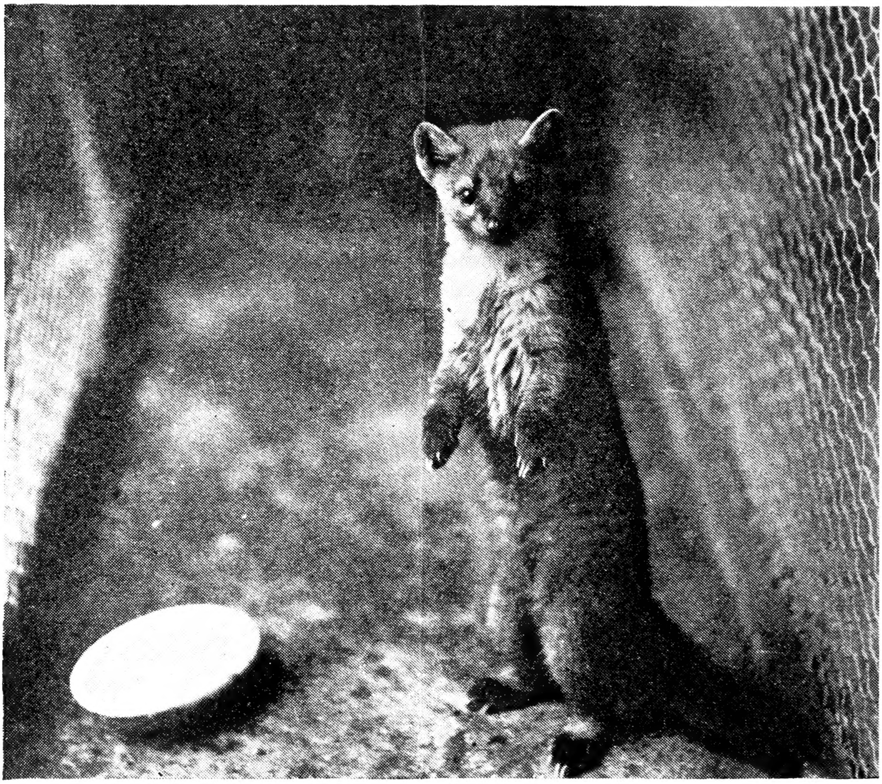

Figure 1.—The marten, one of our most valuable fur animals, is now in danger of extinction.

been under close observation over long periods of time. The place to begin, however, is at the beginning, no matter how elementary it may seem.

RAISING FUR ANIMALS IN CAPTIVITY

Raising animals in captivity as a means of supplying the need for furs is an industry that is both new and not new. The Chinese have for centuries bred sheep, goats, and dogs for their pelts. The outstanding example of a domesticated animal bred specifically for this purpose is the Karakul sheep, which has long been produced for lambskins on the uplands of Bokhara in central Asia. Afghanistan is now perhaps the most important center of this industry, and the annual production of lambskins there is (1936–37) 1,200,000; the

Union of Soviet Socialist Republics is next, with an annual production of 900,000 skins. About 30 years ago Karakul sheep raising was started in what was then German Southwest Africa, and today the farmers of that region are producing annually about 700,000 skins and shipping them to the raw-fur markets of the world. Karakul sheep are also being produced in the United States, but there are few purebred animals in this country. The foundation stock came from small importations from Bokhara in 1909, 1913, and 1914. Further importations are next to impossible. The Federal quarantine regulations prohibit direct importation into the United States, and it is too expensive to make indirect importations by holding the animals for the required length of time in another country.

Figure 2.—**The production of silver foxes on farms now (1936) exceeds 200,000 annually.**

In the face of this situation the Bureaus of Animal Industry and Biological Survey have been cooperating in a breeding experiment that promises favorable results. Since it would be almost impossible to increase the breed to any appreciable extent from present stocks of purebred animals, the Department has been carrying on cross-breeding experiments with Karakul × Black-faced Highland and Karakul × Corriedale at the National Agricultural Research Center, at Beltsville, Md.

The most spectacular and important development in fur-animal production, however, is in silver-fox farming (fig. 2). This development has taken place during the last 40 years, and though brief, the history of the industry has been sensational. Two Canadian farmers on Prince Edward Island, Charles Dalton and Robert Oulton, started to experiment in 1894 with cross and black (silver) foxes, some captured and some purchased. They bred the foxes in captivity and finally obtained some entirely black and silver puppies. The neighbors soon learned of their secret operations and before long several fox farms were established on the island. It was generally understood that Dalton and Oulton were making money, but it was not until the 1910 sales figures were published that the extent of their profits became known. In that year they received for 25 pelts an average price of $1,339. One pelt brought the all-time high price of $2,627. This started a fox-farming boom and sent the prices of breeding stock skyrocketing. The boom collapsed at the beginning of the World War in 1914, but in 1923 people were again investing anywhere from $500 to $5,000 per pair in foxes, which in some cases they had never seen. By 1927 the unhealthy speculation in breeding stock had died out and ranchers went to work producing the animals for the fur.

Production on Fox Farms

Fox farming today represents the greatest development thus far in raising fur animals under strictly controlled conditions. It can still be considered a relatively new industry, however, since practically all the development in production has taken place since the World War. The number of pelts produced and sold in the United States is estimated to have increased from 6,000 in 1923 to 200,000 in 1935. The total value of the sales increased from $819,429 in 1923 to $7,719,600 in 1928. During the next 3 years prices declined because of the depression and the increased production of skins, but from a low point of $3,472,200 in 1931 they advanced to $7,114,500 in 1934.

Foxes are grown successfully throughout the northern half of the United States, from New England westward to Washington and Oregon, and in the cooler parts of California. The greatest numbers of silver foxes are produced in Wisconsin, Minnesota, and Michigan, and these three States are contributing more than 50 percent to the annual crop of pelts. The largest two companies in the world producing silver foxes operate in Wisconsin. Each maintains about 7,600 breeding pairs. The other principal fox-farming centers are in the Rocky Mountain region, including Oregon and Washington, and in the New England States, Illinois, Ohio, New York, and Pennsylvania.

In Canada, fox farming has had a development similar to that in the United States but on a somewhat smaller scale. In 1923 sales of pelts from Canadian fox farms were slightly greater than in this country. In 1935 the number of Canadian pelts sold totaled 120,465. Furs from farms now play an important part in the fur trade of both Canada and the United States. The value of the pelts from farm-raised animals represents approximately 31 percent of the total annual value of the raw-fur crop in the Dominion and 20 percent in the United States.

Abroad, fox farming has had a phenominal development, particularly in Norway, where the industry has grown like a mushroom. During the season 1934–35 the number of pelts produced was 103,604. Other European countries also are producing silver foxes, and in Japan and South America the industry is well established. The European silver fox pelts, especially those from Norway, must now be considered an important part of the world supply. If silver fox farming develops extensively in South America, the farmers of that continent will have a seasonal advantage in getting the pelts to the markets, for pelting there is in July and August.

The world production of silver fox pelts for the season 1935–36 was probably in excess of 500,000 distributed approximately as follows: United States and Canada, 350,000; Norway, 125,000; Sweden, 25,000; Netherlands, 5,000; Denmark, 3,000; Union of Soviet Socialist Republics, 4,000; Germany, 3,000; England, France, Switzerland, Japan, and South America together, 3,000.

It can hardly be doubted that this comparatively new fur-farming industry has become a permanent part of our agriculture. It has met with relatively more success in recent years than most other branches of agriculture, and it promises still greater developments when freed from the artificial restraints and handicaps that at present are retarding its progress. Fur farming fits in well as a side line to general farming

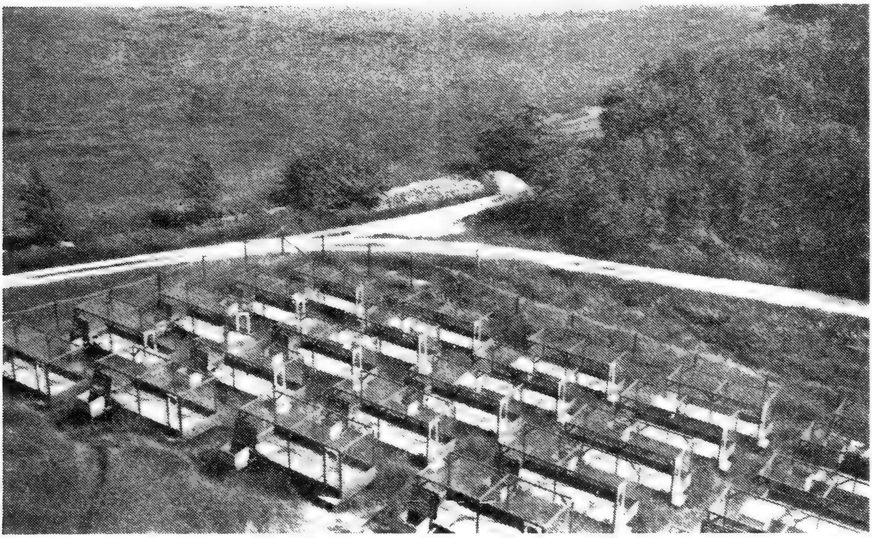

Figure 3.—Many small fur farms like this one in Massachusetts are producing fur as a side line to other agricultural pursuits.

because it can utilize certain parts of the farm not adaptable to growing other crops. It also provides a winter occupation and brings in additional revenue during the season when both are needed to balance farm operations.

In 1926, when the annual production of silver fox pelts in the United States was about 25,000 and the average price for skins was $126, farmers began to worry about the possibilities of overproduction. Many were wondering whether increasing production of furs year after year would not outstrip even the increased demand, including that resulting from the normal population increase. At that time the prices paid for pelts were dropping and the cost of feed was going up. The situation at that time was more alarming to the small than to the large producers.

Today, a decade later, the annual crop of pelts has multiplied eight times, to 200,000. Silver fox fur is fashionable, in fact very fashionable. The average price for raw pelts has dropped to $42, only a third of that realized in 1926. Food costs are increasing rapidly. Some fox farms have grown bigger, others better. Conditions now are not perplexing so much to the small as to the large producers. The reason for this change is that the former does not have all his eggs in one basket—pelt production with him is a side line (fig. 3). Furthermore, pelt production costs him less on the average than it does the

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large producer and the price he receives for a pelt is on a par with that obtained by the latter. The small producers as a group are today marketing more than 140,000 pelts each year, while the large producers contribute only 50,000 or 60,000 to the annual crop.

Experiments with Other Species

Minks, martens, fishers, skunks, raccoons, and opossums also are being raised in captivity to some extent, the most striking developments having been in mink farming. The number of farm-raised

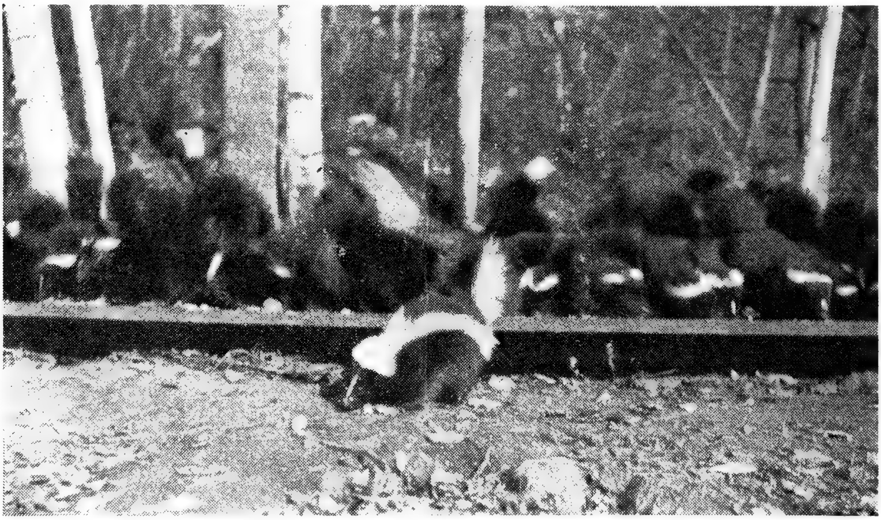

Figure 4.—Skunks are easily raised but not at a profit.

mink pelts has increased rapidly, and the prices paid have been exceptionally good, reaching their high point during the 1936 season. These favorable conditions have naturally stimulated expansion. Generally speaking it may be said that in the case of fur animals other than foxes and minks more money is invested in feeding, breeding, and management than can be realized from the sale of the pelts. For the present, at least, the production of skunks (fig. 4), opossums, raccoons, martens, and fishers for fur is not a profitable undertaking.

The problems of the fur farmer are fundamentally the same as those of other producers of livestock. They include a knowledge of his animals, their physical needs and temperament, and the requisites of sanitation, feeding, breeding, and disease control. In all of these lines, scientific research has a part to play, but so far research has been of very limited extent.

Present Breeding Methods

During the relatively short period that foxes have been raised by man no particular strains of outstanding characters have been developed. The best of them, however, produce fur of high quality. The problem then becomes one of producing fur of a given character and quality with greater certainty. In addition, the fox farmer would like to be sure of getting good producing vixens in order to increase his pup crop; and he would like to have greater control of diseases and parasites, some of which are common to domestic livestock and some peculiar to foxes. The disease problem has been paramount, as the losses on fox farms in certain sections of the country have been disastrous, in some instances entire ranches having been wiped out. The application of veterinary science is aiding in developing the industry, although research has not yet developed methods for complete protection against several diseases that are causing heavy losses on fox farms.

The accumulated knowledge developed by plant and animal breeders should be of great value to fur farmers, but the latter have been slow in applying it to fur-animal production. In the past, time given to promotional schemes for selling breeding stock to unsuspecting buyers was much more lucrative than that devoted to the tedious study of basic principles of fox breeding, feeding, and disease control. Then, too, the rapid shift in the market requirements from dark to full silver pelts has kept the farmers busy—and worried—supplying the demands of fashion.

In their breeding operations, fox farmers have primarily stressed the selection of particularly good, true-breeding types and the use of such animals as breeding stock. Increased prolificacy and the production of fur of high quality have been the main objectives. The fur farmer has not advanced so far as the breeder of domestic livestock in the application of definite breeding principles to his problems. Among fox farmers in general, there is as yet no idea of developing a fox strain different from any now in existence and perhaps possessing outstandingly valuable characters. Such good specimens as have been developed have resulted from continued selections for a few desired types.

Market Requirements

It must be said, however, that the vagaries of fashion have had a good deal to do with the failure thus far to set up certain definite long-time objectives. Forty years ago black fox was popular; a few years later the highest prices were being paid for quarter and half silvers; and during the last 4 or 5 years the full silvers have been setting the upper price limits because they are in keen demand for working into short and long capes, short coats, enormous collars, and wide trimmings on fur coats, cloth coats, and dresses. In 1936 the prices obtained in the United States for full silver pelts were 50 percent higher than in Great Britain.

These shifts in market requirements necessitated strenuous efforts on the part of breeders to satisfy present demands, with a minimum of attention to the future. Charles E. Kellogg made an exhaustive study of the silver-fox-pelt markets of the United States and Great Britain covering the 5-year period 1932–36 to determine the effects of trends on the percentages of silver in the pelts. The results showed that about 36 percent of the American offerings in 1936 were full-silver skins, an increase of 225 percent during the 5-year period.

This demonstrates how quickly the majority of farmers produced the maximum of light-silver pelts. Some cautious breeders, however, are retaining some of the darker silvers in the breeding herd as an insurance reserve, in case there should be a sudden return to the half and three-quarters silvers, which are more satisfactory for scarf purposes. Other breeders feel confident that the genetic make-up of silvering is dependent upon so many factors that persistent selective mating toward darker colors would supply such a new demand just as effectively, though perhaps somewhat more slowly. They feel that their method permits maximum concentration on full silvers for the present higher prices. There are no authentic scientific data available to demonstrate that either method is correct, and thus the producers continue to be faced with an important problem that for the present remains unsolved.

RESEARCH IN INHERITANCE IN THE FOX

It is quite generally appreciated that there is still much room for improvement in the color and texture of silver fox fur. The pelts now coming to the market are generally somewhat better in quality than a year ago, but this is true mostly for individual ranches rather than for sections of the country. Since the number of pelts offered for sale is increasing year after year, buyers are naturally becoming more discriminating, especially with the increased competition that now involves other countries as well as the United States. Fox farmers have reached the point where they must exert every possible effort to improve the quality of the fur produced. For the present, close culling of the breeding stock, which means pelting the undesirables, and intelligent and strict selection of breeding animals are the most certain methods to bring about a marked improvement in fur quality.

To meet the need for fundamental information on the genetic basis of silvering, the Biological Survey began an experiment in 1935 at the United States Fur Animal Experiment Station, at Saratoga Springs, N. Y. An attempt is being made to determine, if possible, the genetic factors involved, so that market requirements can be met more promptly. The objective is to determine the relationships between the various degrees of silvering and to work out methods of breeding that will enable the breeder to have more control over them. Only a small number of foxes is available for this experiment, whereas experience proves that a large number must be used to obtain definite results where many genes are concerned. There has been only one other research program to trace the inheritance of fur colors, and this was concerned not with gradations in silvering but with the basic differences between red, cross, and black (silver) foxes. To make this clear, it is necessary to give a brief account of these different types.

Before the development of fox farming, there apparently occurred in the common red fox (*Vulpes fulva*) two distinctly different mutations to black. One of these, namely, that to which the standard or Prince Edward Island silver fox traces its origin, must have occurred somewhere in Canada, probably in the eastern or central part. The other, to which the Alaskan silver fox traces its ancestry, certainly must have occurred in Alaska, most likely in the interior. The so-called cross fox was probably produced by crossing the red and the silver (fig. 5).

Thus foxes of the genus *Vulpes* may have three kinds of pelts: (1) The common red fox, which is primarily red or fulvous with a mixture of gray or brown except for restricted black markings on the feet and ears, a white area at the end of the tail, and certain white-banded hairs on the back and rump; (2) the typical cross fox, in which black predominates on the feet, legs, and under parts, while red or fulvous overlying black covers most of the head, shoulders, and back; and (3) the black (silver) fox, which carries no red or fulvous, the entire pelage being dark at the base and heavily or lightly overlaid with the banded guard hairs that produce the silvery appearance. These guard hairs are not entirely white but are black with a white band, and some are entirely black. Foxes of the third group vary from animals that are almost entirely silver to those that are entirely black except for a few white-banded guard hairs on the back and rump. The fur trade recognizes five classes of silver fox pelts, graded according to the percentage of silver, as follows: Full, three-quarters, half, one-quarter, and slightly silver or dark.

Figure 5.—**Litter of pups resulting from cross-breeding a silver with a red fox.**

It is believed that what are called standard silver foxes, carrying a factor for silver and black color, were found naturally in many parts of Canada. Few if any of these foxes migrated into Alaska. On the other hand, the progeny of Alaskan silver foxes, also carrying a factor for the silver and black color, probably traveled southward over the mountain range and spread over a large part of Canada. Neither the Alaskan nor the standard silvers migrated to any extent south of the Great Lakes and the St. Lawrence River. The indications are, however, that some foxes possessing either or both of these factors for silver and black must have migrated or occurred naturally south into the northern parts of the States bordering on the Great Lakes.

In the early days of fox farming, red and cross foxes captured in the wild were bred to produce silvers. As more silver foxes became available, they replaced the red and cross foxes on ranches, and silver foxes were bred together to produce silvers. As time went on foxes that would breed true for silver were developed and it became generally understood that silver foxes produced from silver fox parents would always breed true. Later on, however, when silver foxes originating in Canada were bred to silver foxes from Alaska, the young produced proved to be crosses and not silvers.

Genetic Relationships Between Red, Cross, and Black Foxes

Prior to 1928 no scientific research had been conducted to determine the genetic basis of the red, black (silver), and cross coloring in foxes, and consequently there was considerable confusion as to the genetic relationship between the black color in standard and in Alaskan foxes. In 1928 it was decided to include such studies in the program of research for the United States Fur Animal Experiment Station. B. L. Warwick, of the Texas Agricultural Experiment Station, cooperated with the late Karl B. Hanson, of the Fur Animal Station, and proposed a hypothesis that would account for the results obtained. To clarify the discussion somewhat, this hypothesis will be given first. Warwick suggested that genes *A* and *B* and their alternative forms (alleles) *a* and *b* account for red, black (silver), and cross colors in foxes. All the possible combinations of these genes would give the following types:

AABB=Alaskan red.	*AABb*=Smoky red.	*AAbb*=Standard black (silver).
AaBB=Cross.	*AaBb*=Blended cross.	*Aabb*=Substandard black.
aaBB=Alaskan black (silver).	*aaBb*=Sub-Alaskan black (silver).	*aabb*=Double black.

Hanson found that when the standard black and the red foxes were crossed, the offspring were usually a smoky red. Although red was strongly dominant to black, it was not completely dominant; there was some blending that produced the smoky color. Foxes of the first filial generation had larger prominent dark points and more evidence of black than is usually present in the red parents. Segregation into reds, smoky reds, and blacks occurred when the first-generation offspring were bred inter se, that is, bred to their own kind. The ratio of segregation was about 1 red to 2 smoky red to 1 black. When smoky red foxes of the first filial generation were backcrossed to the black parents, the result was a ratio of 1 smoky red to 1 black. These ratios indicated that a single gene accounts for the difference between pure standard blacks and reds.

On some fox farms, however, where supposedly pure standard black foxes were bred with pure red ones, mixed litters of smoky reds and reds in about equal proportions were produced in the first generation. Doubtless the black (silver) parents were not pure but had a hybrid combination of the genes *A* and *a*.

Some red foxes caught in the wilds of Canada, the Upper Peninsula of Michigan, and northern Minnesota and Wisconsin when crossed with pure standard blacks produced mixed litters, with blacks and smoky reds in equal proportions. If these wild red foxes were really hybrids or smoky reds, it would account for the results.

When Alaskan blacks were crossed with red foxes, the first generation were all cross foxes, but no appreciable dominance of black or red was in evidence. When the first filial generation was bred inter se, there was a segregation of 1 red to 2 cross to 1 black (silver). The cross foxes when backcrossed to black parents again produced crosses and blacks in equal proportions. The ratios again indicated a difference of one gene between pure red and pure Alaskan silver foxes.

Hanson then crossed Alaskan and standard black (silver) foxes. The first filial generation turned out to be blended cross foxes. This

KEY TO GENETIC TYPES

RED *AABB*	SMOCKY RED *AABb*	STANDARD BLACK *AAbb*
ALASKAN RED CROSS FOX *AaBB*	BLENDED CROSS FOX *AaBb*	SUB-STANDARD BLACK *Aabb*
ALASKAN BLACK *aaBB*	SUB-ALASKAN BLACK *aaBb*	DOUBLE BLACK *aabb*

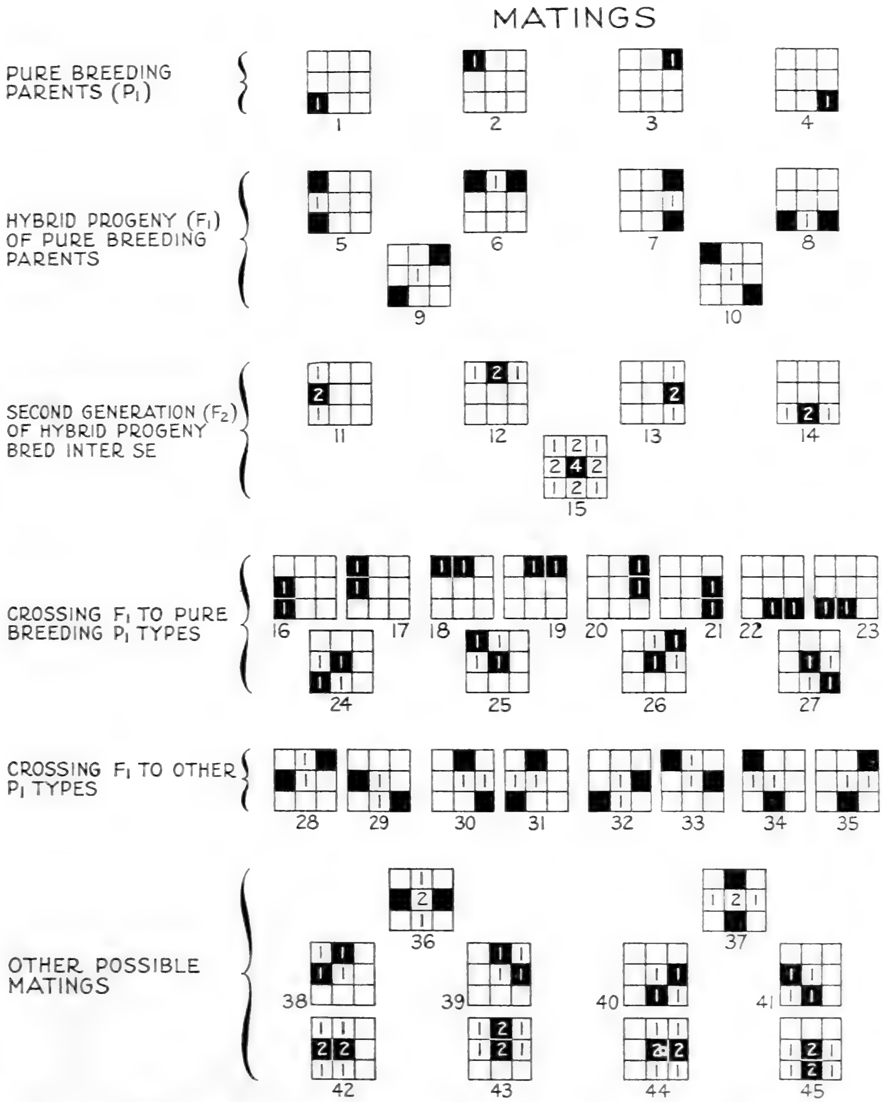

Figure 6.—Diagram illustrating the genetic types of foxes and the results of various matings on the basis of a two-factor inheritance. Black squares represent matings, and numerals within the squares represent the expected distribution of progeny in proportions.

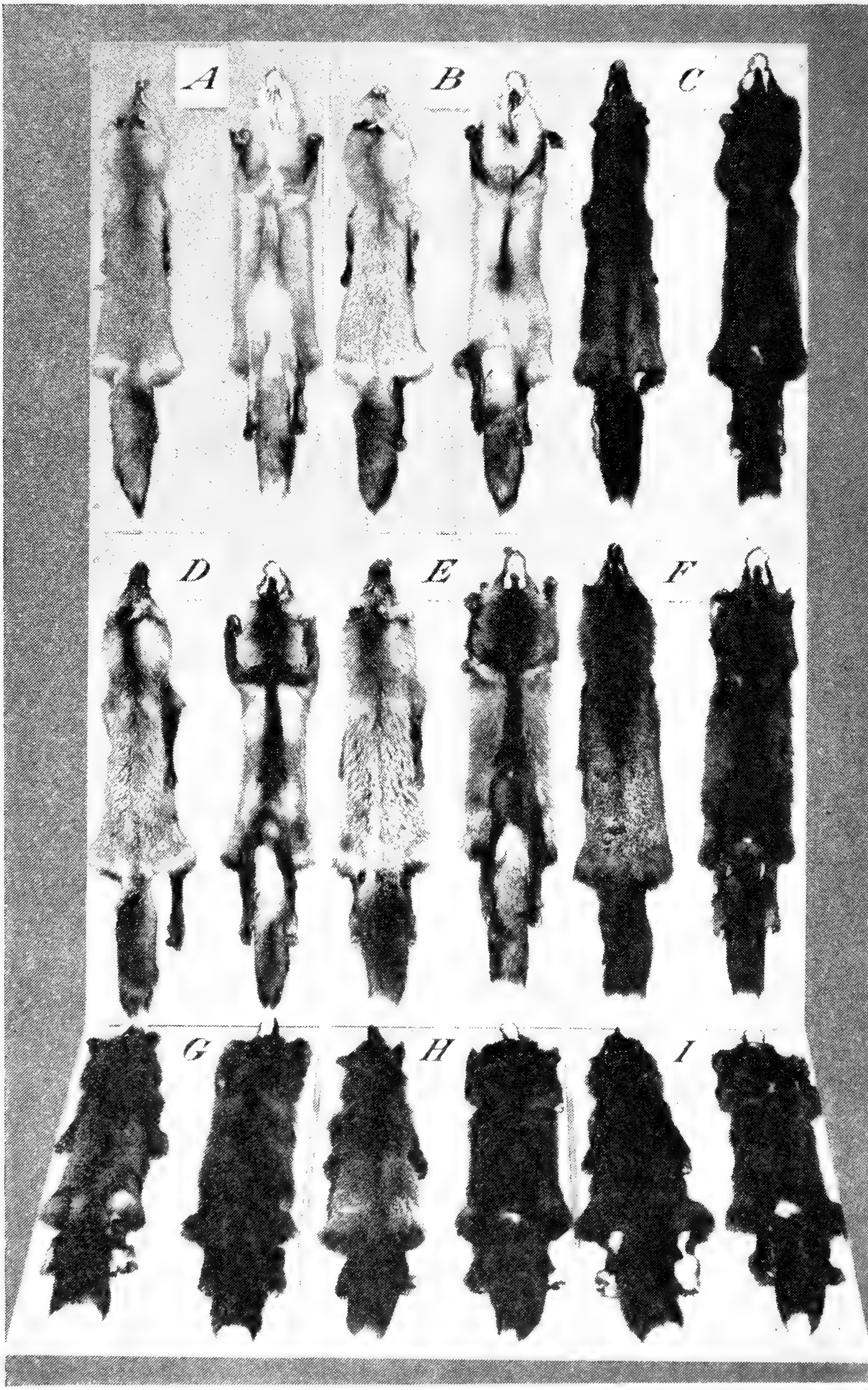

Figure 7. (Legend on opposite page)

indicates that two different genes are involved in Alaskan and standard black foxes.

In some instances when Alaskan blacks and standard blacks were mated, black young occurred in the litters. Check matings demonstrated that the occurrence of black in the first filial generation was due to the fact that one or the other of the parents was not pure but hybrid for either *A* or *B*.

Inadequate facilities and lack of funds made it impossible to maintain a sufficient number of foxes at the Fur Animal Station to make a complete investigation of this kind. Therefore, the research workers had to solicit the cooperation of fox farmers who had been conducting cross-breeding experiments in the United States and Canada. They willingly furnished the data obtained from their breeding operations, and these proved to be most valuable in amplifying the results obtained at the experiment station.

Hanson made a biometrical analysis of these data and found that three principal colors in foxes are inherited in accordance with the factor hypothesis previously mentioned. In 775 litters, including over 3,000 pups, representing 30 different combinations of types, only 4 litters were reported in which the results were contrary to the hypothesis. In at least two of these cases there was some doubt as to whether the vixen was served by two different males or whether the parents were improperly classified as to color.

Hanson designed a chart to illustrate the results of the various matings on the basis of two-factor inheritance (fig. 6). At the top of this chart is a key to the three different colorings and the nine different combinations of genes that result in nine different types. Directly under the key is a series of smaller nine-block squares giving the 45 different mating combinations of these nine types. The black squares in the blocks represent the genetic types mated and the numerals represent the expected distribution of progeny in proportions. Reference should be made to the key at the top of the chart to determine the colors (fig. 7) and genetic make-up of the animals being mated and also the progeny.[2]

As examples of the use of the chart: Suppose Alaskan blacks are to be mated with standard blacks. This mating is given in the set of

[2] In matings producing more than one kind of progeny the result may deviate in the distribution of progeny in individual litters or in a small number of litters, not only among foxes but among other animals also. For example, the expectation from crossing a substandard black with an Alaskan black (fig. 6, square 32) is that the progeny will consist of blended crosses and sub-Alaskan blacks in a 1:1 (50:50) ratio. As likely as not, this mating will produce an equal number of crosses and blacks (silvers). The probable occurrence of different combinations of cross and black foxes in litters of four thus produced is as follows:

Black (silver) foxes	4-3-2-1-0
Cross foxes	0-1-2-3-4
Total	4-4-4-4-4

Although these figures represent the proportion of black (silver) and cross foxes that may occur in litters of four, litters of that size do not always occur. In sufficient numbers there would be produced six times as many litters containing equal numbers of silver and cross foxes as there would be litters of all silvers or all crosses. Likewise the litters with three pups of one color and one of the other would be produced four times as frequently as would be litters of all one color.

Figure 7.—Fox pelts of the nine genetic types, upper and under side illustrated in each case, and grouped as in the square diagram in figure 6: _A_, Red, _AABB; B_, smoky red, _AABb; C_, standard black, _AAbb; D_, Alaskan red cross fox, _AaBB; E_, blended cross fox, _AaBb; F_, substandard black, _Aabb_; _G_, Alaskan black, _aaBB; H_, sub-Alaskan black, _aaBb; I_, double black, _aabb_.

squares numbered 9. The figure 1 in the middle square indicates that all the progeny will be blended cross foxes. Now suppose these blended cross foxes are bred together, as in the set of squares numbered 15. The figures in the squares indicate that every kind of fox will result from these matings, and that in a large number of matings the proportions may be expected to be 4 blended crosses, 2 Alaskan red crosses, 2 smoky reds, 2 substandard blacks, 2 sub-Alaskan blacks, 1 red, 1 standard black, 1 double black, 1 Alaskan black. If an Alaskan black is mated with a smoky red, as in the set of squares numbered 31, the result will be 1 Alaskan red cross to 1 blended cross. If a sub-Alaskan black is mated with an Alaskan red cross, as in the set of squares numbered 41, the result will be equal numbers of Alaskan red crosses, blended crosses, Alaskan blacks, and sub-Alaskan blacks.

A SUGGESTED PROGRAM FOR FURTHER RESEARCH

Fur farmers look to the scientist for leadership in the development both of basic information in fur-animal breeding and of methods of improvement, and they have appealed many times to the Federal and State Governments for assistance. Little has been done, however, by public agencies to develop this new and promising animal-production enterprise, and there has been no systematic effort on the part of State agricultural experiment stations or the Department of Agriculture to develop, isolate, perpetuate, or record fur animals of superior breeding ability.

In order to place fur farming on a foundation comparable with that of other branches of agricultural production, fundamental knowledge is essential, and this can be obtained only by inaugurating a comprehensive program of research. Such a program might be conveniently divided into three parts:

1. Research work on reproductive cycles. Most of the study thus far has been concerned with domestic species, and the available definite information on wild animals is very meager, particularly as regards species of economic importance. A more exact knowledge of the reproductive cycles of North American fur animals could be applied in several ways. It would be of great value—(a) in determining the proper trapping seasons for restoring and conserving fur animals; (b) in attempting intelligently to supplement the natural supply by restoring and transplanting; (c) in insuring success in producing fur species in captivity; and (d) in making possible a more efficient and economical control of predatory and other injurious species. The object of research on reproductive cycles would be to establish definitely—(a) the breeding period of valuable fur animals; (b) the number of litters and young produced yearly; (c) the type of embryonic development (whether uninterrupted or with a delay in implantation); (d) the hormone control of the breeding cycle; (e) the feasibility of artificial insemination in those species that might be raised in captivity; and (f) possibilities for producing or maintaining reproductive fertility by hormone or other treatment.

2. Breeding experiments with various fur animals under controlled conditions. These should be conducted to study the inheritance of prolificacy and fur quality, which includes color, sheen, and density.

In all animal breeding it is vital to concentrate on as small a number of objectives as possible. Measurements must be devised to evaluate all these characteristics with greater certainty, especially fur quality. Similarly, there should be measurements for efficiency of feed utilization, since the cost of feeding is a large part of the cost of production. Where genetic factors (genes) might be directly useful, as in the case of coat colors, they should be determined so far as possible. They will doubtless prove to be extremely complex, but the research on color inheritance already described indicates that something may be done to segregate definite traits of this kind and to breed for them. Meantime, to use breeding stock of proved performance, as determined by the progeny test and by dependable records of parental characteristics, would be to approach the problem in the way that has proved to be of such great value in other branches of livestock breeding.

3. Attention to nutrition. This article is concerned primarily with breeding and genetic research, but in any comprehensive research program, nutrition is equally important. Practically no fur-animal research studies have been conducted on digestion and metabolism, the chemical composition of foods, and the part played by various foods in growth, fattening, maintenance, reproduction, and the economical production of pelts of high quality. With few exceptions, all fur animals are meat eaters. The maximum and minimum quantities of red meat that can be fed during the various stages of development should be determined. Some work has been done to determine the value of cereals, vegetables, and protein supplements in the ration, but it should be expanded. These and many more nutritional problems when adequately solved will enable fur-animal breeders to proceed more surely, safely, and efficiently.

Without extensive controlled experiments, all breeding and feeding practices are of a hit-or-miss nature. But experiments with fur animals are exceptionally costly, not only in the matter of equipment, but also in the time involved, for breeding stocks are expensive and practically all species produce only one litter a year. In addition, scientific training and the ability to conduct research are required, and the economic results of any given project are by no means certain. Private breeders therefore are not likely to do much experimenting, because they must confine themselves to operations that are fairly certain to produce immediate profits. Fur-farmers' organizations or wealthy producers might undertake some forms of research work, but men change their minds and associations change their policies, and under these conditions there is no assurance of continuity. There are many reasons why fur-animal research must be conducted primarily by properly equipped public institutions, but this can be done only in response to a sufficient public demand and with the active support of those who have a stake in the industry.